

Fuel and Combustor Concerns for Future Commercial Combustors

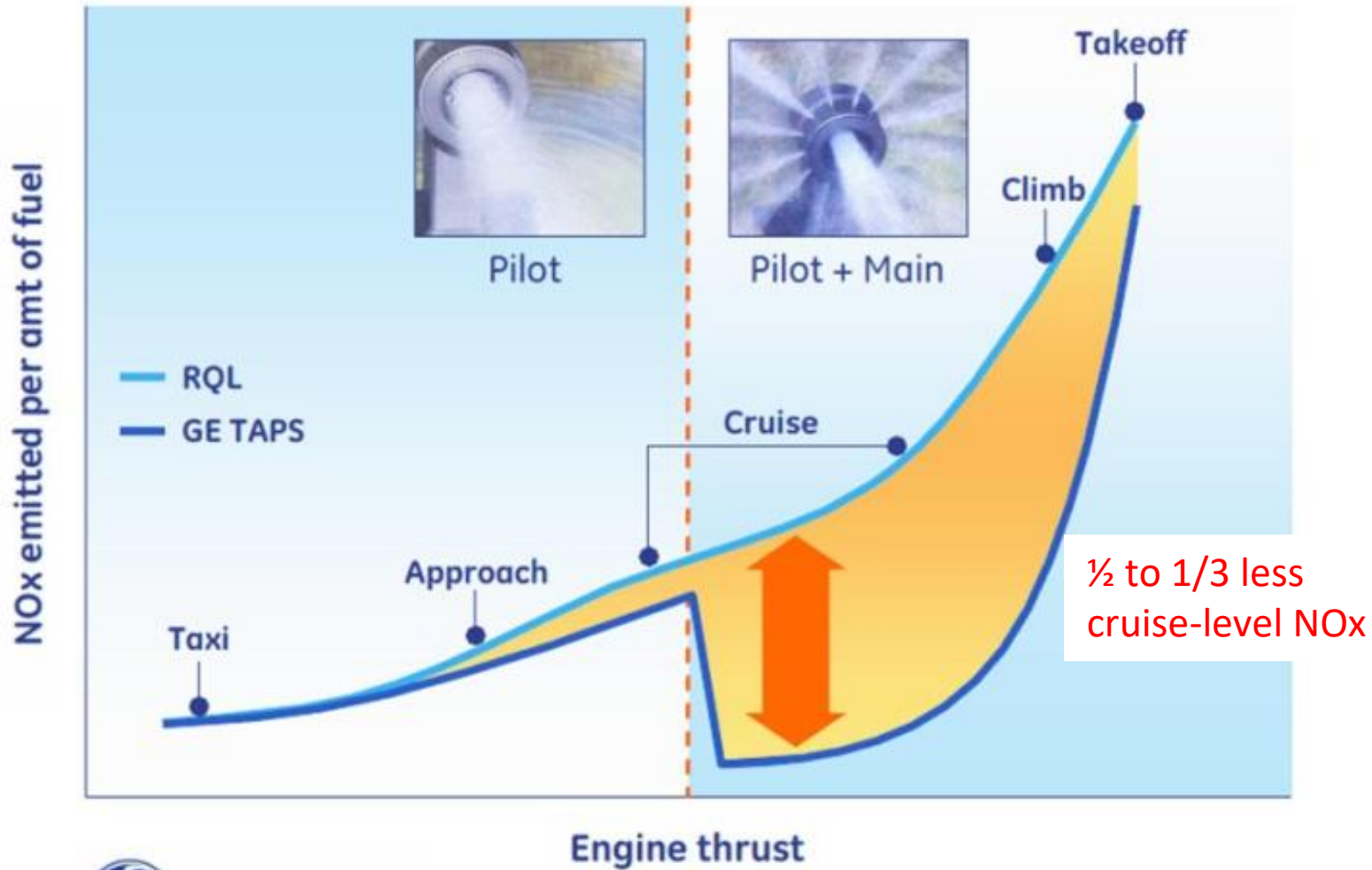
Clarence T. Chang
Engine Combustion Branch
NASA Glenn Research Center
Cleveland, Ohio, USA

ASME Turbo Expo 2017 Panel session 4-36
June 27, 2017

Points to Make

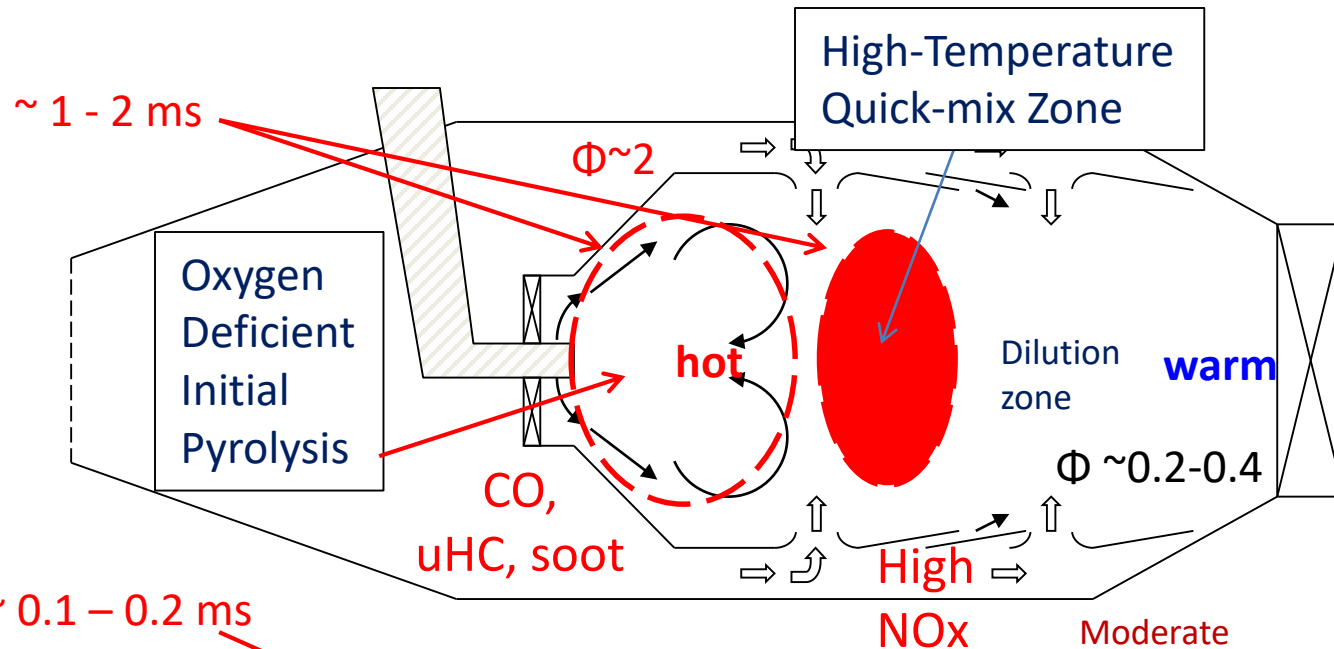
- Lean-burn for future commercial transports
- Lean-burn dependent upon fast fuel-air mixing
- Engine OPR limits lean-burn strategy
- Branch-chain can increase mixing time and lower NO_x
- May need to maintain some light n-paraffin for ignition
- Fuel hydro-treatment removal lower soot, reduce coking

Lean-burn Advantage at Cruise



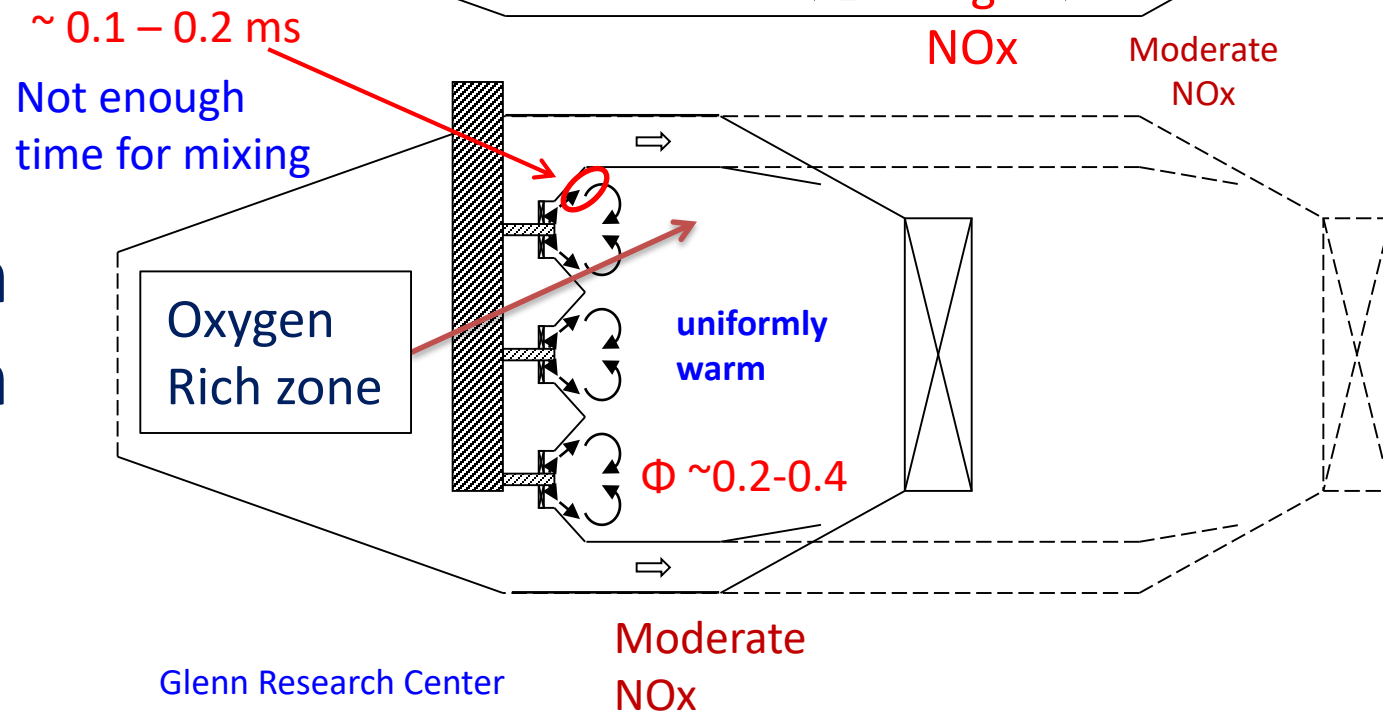
Lean-Burn: Avoid making CO & soot in the first place

Rich
burn



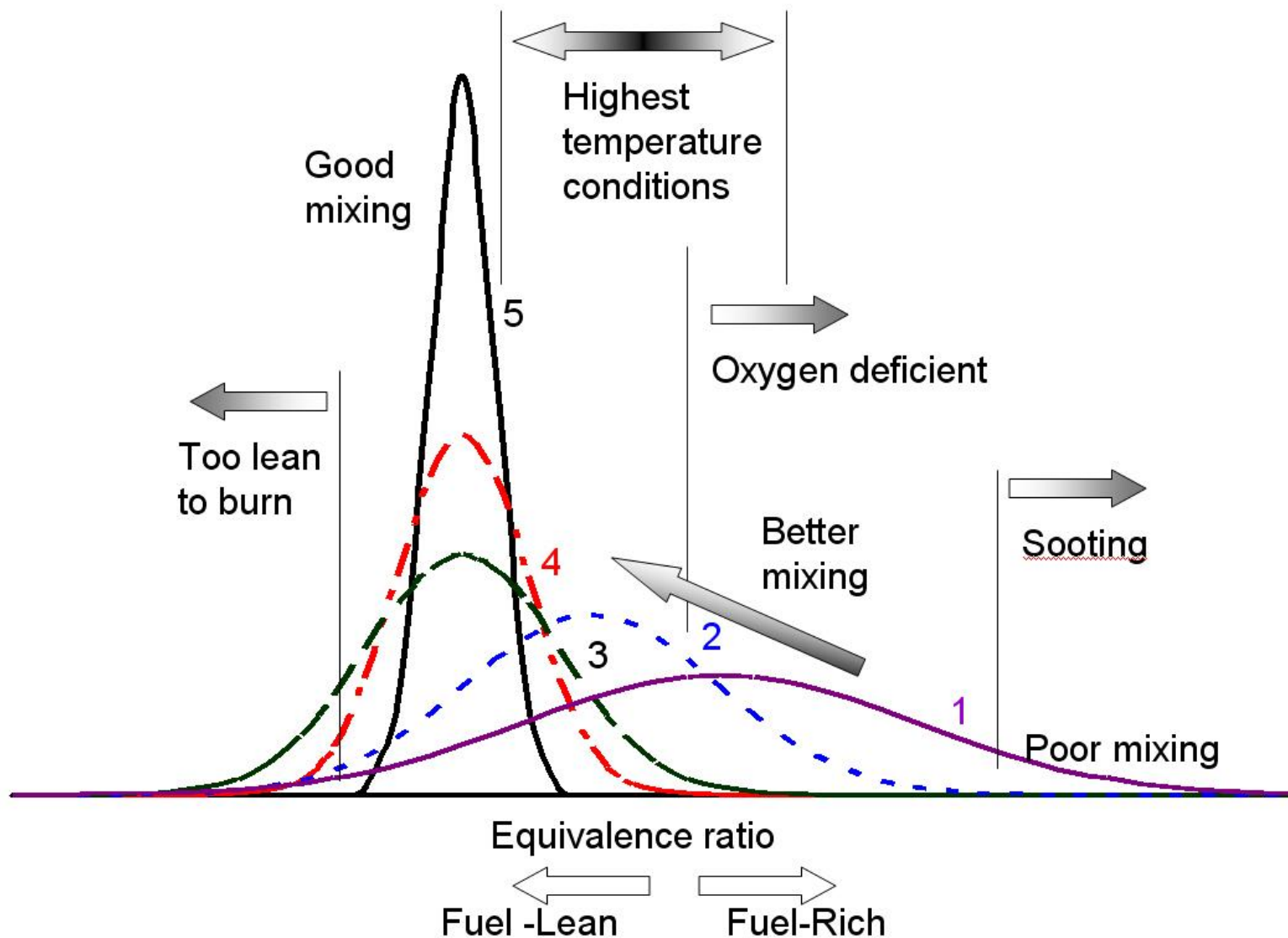
Less
sensitive
to fuel
variation

Lean
burn

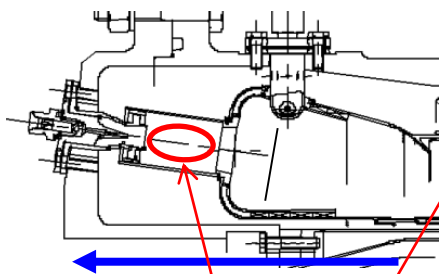
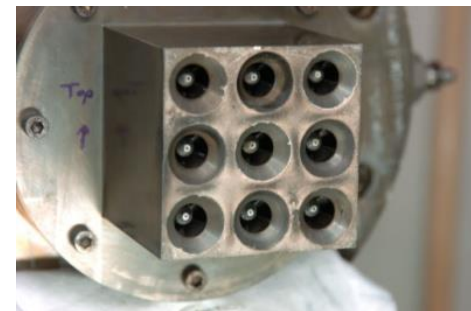
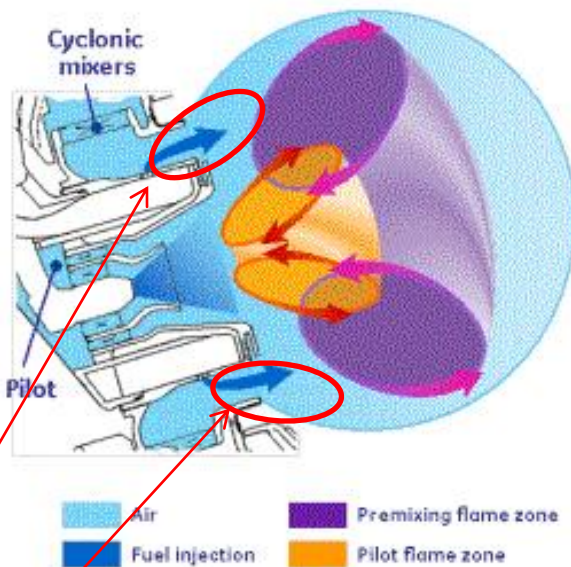


Possible
Low-Power
ignition and
High-Power
auto-ignition
and coking
issues

Quick Fuel-Air Mixing Critical to Clean Combustion



Maximum Combustor Pressure Dictates Viable Lean-burn Combustor Strategy



Lean Premixed Prevaporized

Lean Partial-Premixed

Lean Direct Injection

Max Combustor Pressure

Pre-mixing zones

sensitive to auto-ignition

Higher inlet temperature, Shorter ignition delay time, Less mixing time, Higher NOx

Fuel Variation Concerns on Lean-Burn

- **Coking**: Limits minimum orifice size →
 - Limits atomization rate → Higher NO_x
- **Auto-ignition / Flashback**:
 - Hardware damage
 - Unanticipated dynamics
- **Lean blowout**: Engine stability

Fuel Tweak Opportunity:

Fuel hydro-treatment (Injector **coking** reduction)

Aromatic reduction (Soot reduction)

(Lower liner heat load)

Sulfur removal (Contrail reduction)

Cetane number control

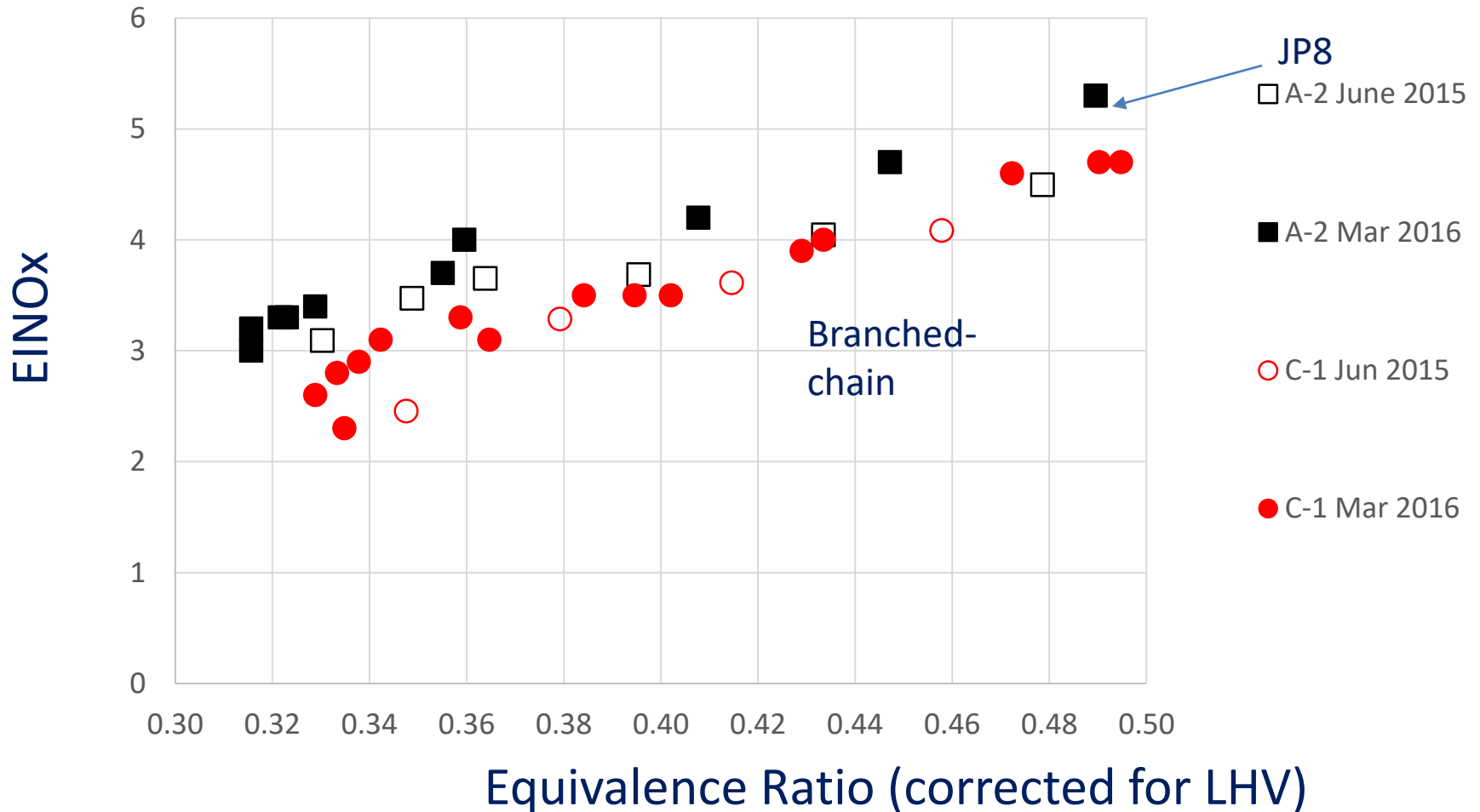
Limit n-paraffin content (Increase ignition delay)

Improve auto-ignition margin

Maintain some light n-paraffin for ignition

Cetane Number: Slower Branched-chain Pyrolysis

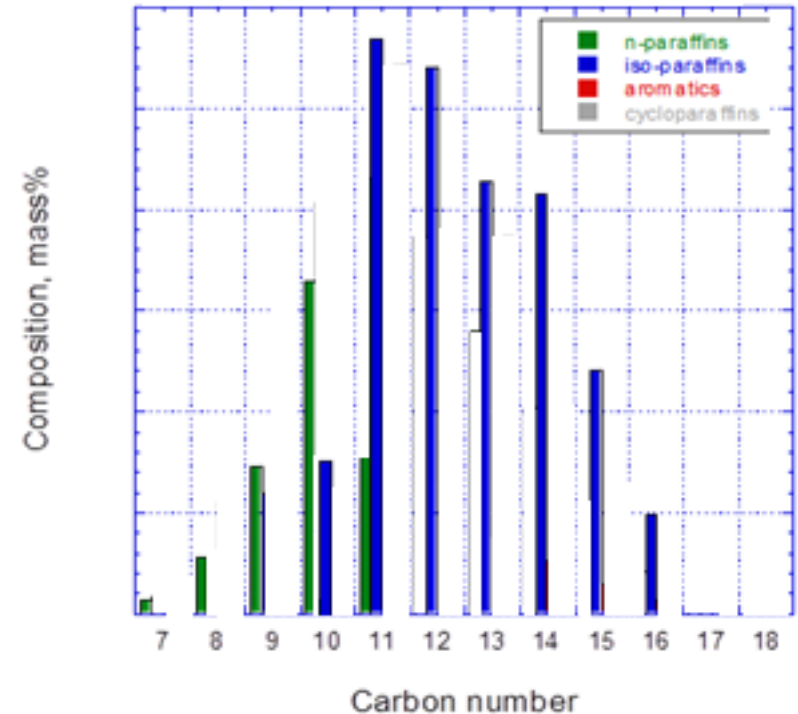
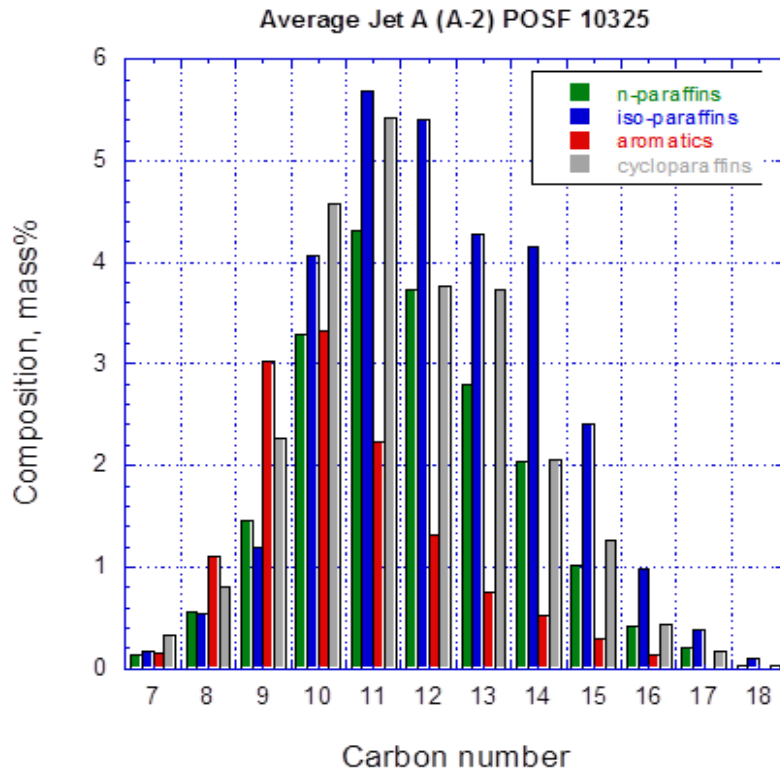
Give me a little more mixing time...



But... Lower-Power Operation...

- Do not atomize fuel well
(slow fuel flow, low air density)
- Vaporize fuel slower
- Poorer fuel-air mixing
- More unburnable fuel-air packets
- Needs faster burning (n-paraffin) components
- Perhaps... Need light n-paraffin components to maintain ignition characteristic

Selective Carbon-number Distribution?



- Limit $C < 7$ for fuel tank flammability
- Limit $C > \sim 16$ (or really heavy stuff) to avoid prolonged localized fuel-rich condition
- Need enough **light-end fraction** for low-power ignition (for fuel vaporization rate control)

Summary

- Lean-burn NO_x and nvPM advantage at cruise
- Fuel injector performance critical to lower NO_x
- High OPR lowers available mixing time
- Controlled fuel composition (cetane number) to bracket ignition characteristic
- Maintain enough light n-paraffin for low power ignition.
- Hydro-treatment to reduce coking